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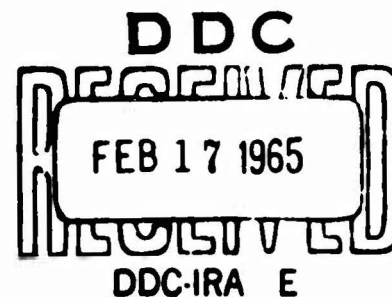


FIELD TEST AND EVALUATION OF A HELIX OPEN PERIODIC FILTER

John J. McCabe, RADC

TECHNICAL REPORT NO. RADC-TR- 64-559

January 1965



Vulnerability Reduction Branch
Rome Air Development Center
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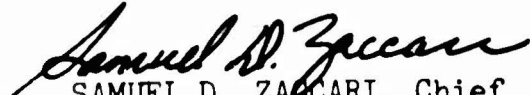
John J. McCabe, RADC

FOREWORD

The field test and evaluation of a helix open periodic filter was performed under system 760G, project 4540, and task 454003. The work was accomplished under the direction of John J. McCabe, EMCVR.

This technical report has been reviewed and is approved.


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ABSTRACT

This report presents the test results and evaluation of a feasibility model of a helix open periodic filter.

Analysis of the data indicates an infinitely wide stop band with a minimum attenuation of 50 db and observed rejections as high as 70 db. Pass band data indicates a loss of less than 0.4 db and a VSWR of less than 1.6:1 across most of the pass band. The filter was capable of accommodating the full output power (minimum of 2 MW) of the AN/FPS-65 at all frequencies.

The filter tested demonstrated the feasibility of using open periodic structures for high power microwave filtering and their advantages over currently used techniques.

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FIELD TEST AND EVALUATION OF A HELIX OPEN PERIODIC FILTER

INTRODUCTION

Spurious and harmonic energy generated by high-power radar and communications transmitters has, in recent years, produced many electromagnetic compatibility problems. As a result, a great deal of effort has been expended to suppress or control this unwanted radiation. To date, the most successful approach to the problem has been the use of various external filters in the system. Some techniques which have proven to be very useful are the resonant cavity, the leaky wall, the ferrite and the waffle-iron filters. But each of these techniques possesses at least one or more undesirable and inherent limitations.

During the last two years, Stone* has, based on the work of Birdsall and White, developed the open periodic filter, perhaps the most significant contribution to the high power microwave filtering art in several years. These filters most nearly exhibit the characteristics of the ideal high power microwave filter, inasmuch as they have an infinitely wide stop band, can accommodate high power with low reflection and loss, and are mode independent.

The purpose of this report is twofold. First, it evaluates the feasibility model of a helix open periodic filter, developed by the General Electric Company under RADC Contract AF30(602)-2955, in a high power multimode field situation. It should be emphasized that the filter tested is a mode-independent, frequency-sensitive device and only under a multimode condition can this, the most significant characteristic of the filter, be

*1. R. H. Stone, R. Z. Gerlack and C. K. Birdsall, "Suppression of Spurious Emissions," RADC-TDR-64-227.

demonstrated. Laboratory tests, generally, only provide rejection data for the TE_{10} and TE_{01} modes, while field tests on an actual radar provide the over-all attenuation characteristics of the filter for all modes.

Secondly, the report indicates the degree of success in achieving the design goals set forth for this effort - that is, an insertion loss of less than 0.1 db, a power handling capability up to at least 10 megawatts, a VSWR of less than 1.4, and a harmonic and spurious frequency attenuation of at least 60 db.

No attempt will be made here to discuss the theoretical development of this filter, since this is the subject matter of Reference 1. However, a brief description of the filter, shown in Figure 1, and its operation follows.

The filter consists of three basic and essential parts: the open periodic transmission circuit for propagation and radiation of the desired and undesired energy, respectively; an input and output transition (similar to a waveguide to coaxial transition) to couple from the fast transmission line to the slow wave helix structure; and absorbing material to absorb the radiated energy.

Basically, filtering takes place in this device as a result of the "allowed" and "forbidden" regions of the open periodic structure. The "allowed" region corresponds to the pass band and is established by choosing the phase characteristic of the open structure (helix) so that only one mode of guided propagation exists in the allowed region. Throughout the "forbidden" region or stop band, the undesired energy is radiated from the structure in a fashion similar to that of an antenna and absorbed in the surrounding absorbing material. In the pass band, the loss depends

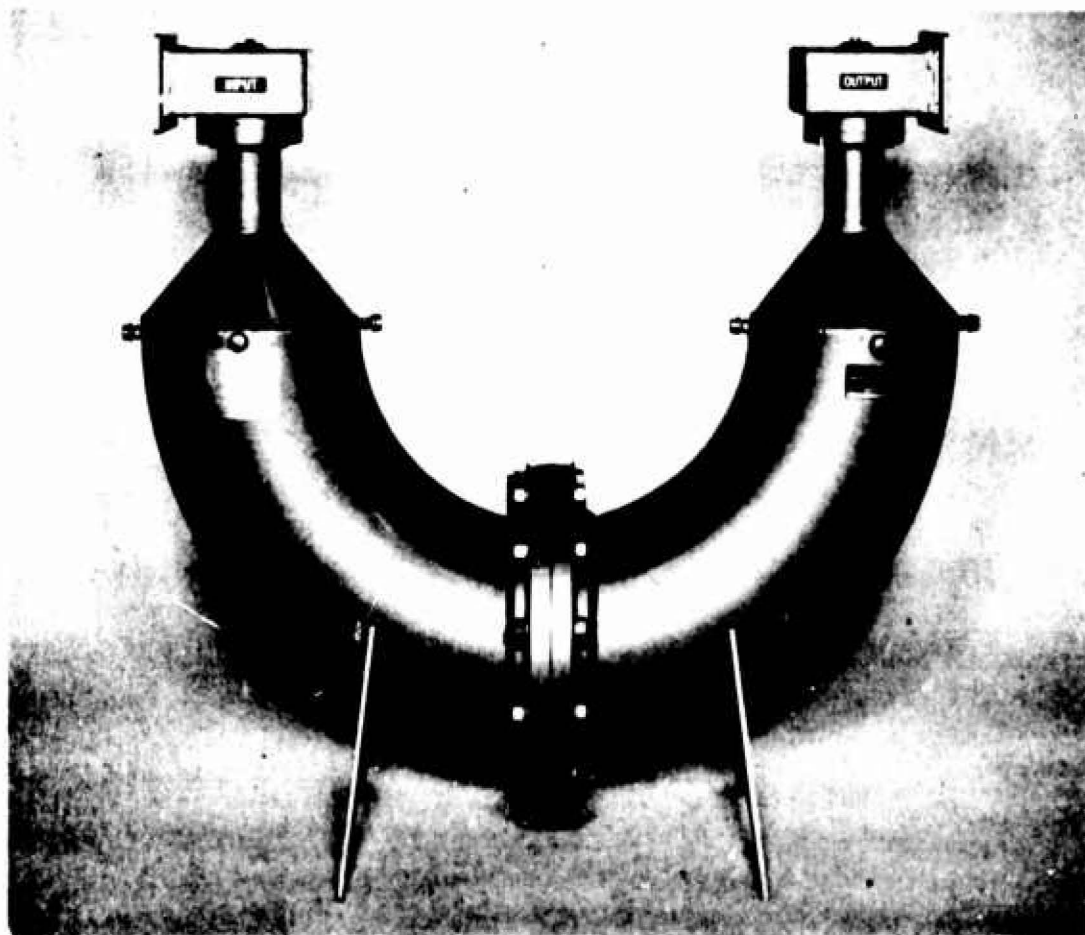
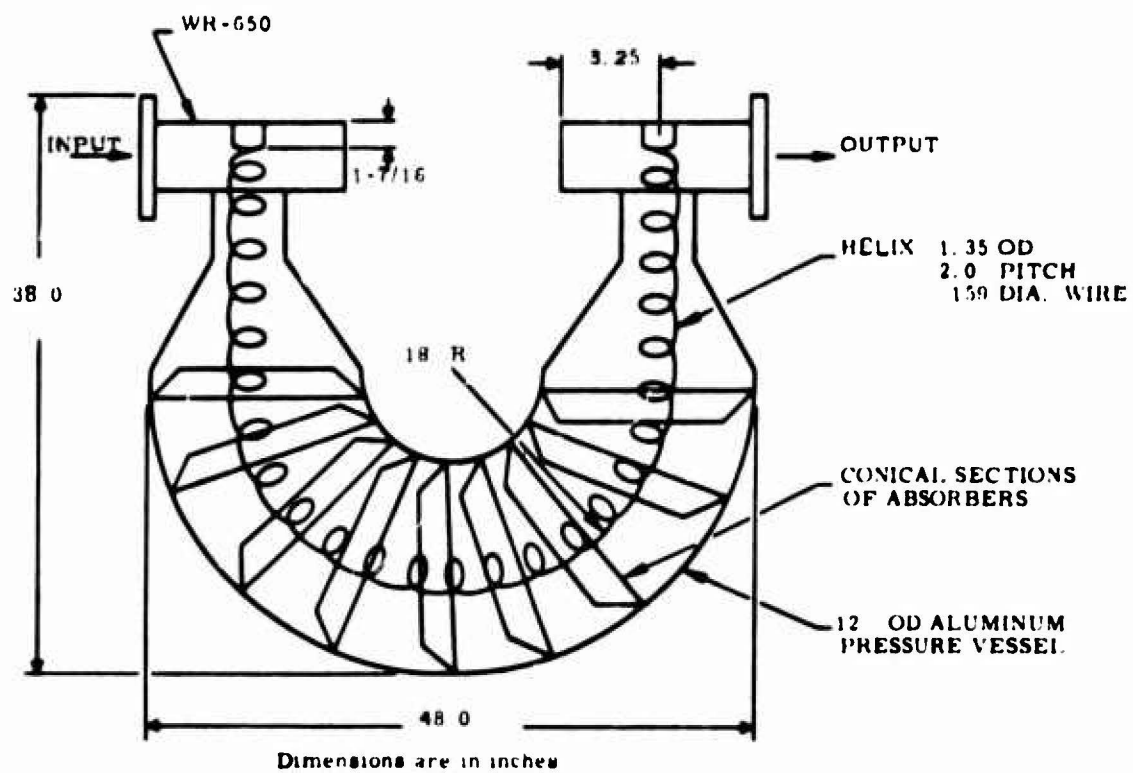


Fig. 1 Outline and Photograph of WR-650 Helix Open Periodic Filter

upon the intrinsic or resistive loss of the structure, the launching efficiency of the transitions, and the scattering caused by curving the open structure. Stop band loss depends upon the launching and receiving isolation, absorber efficiency, and the length and curvature of the structure.

TEST PROCEDURE

The major portion of the tests conducted on the open periodic filter, shown in Figure 1, consisted of high power operation on an actual radar system under normal field conditions. Supplementary low power lab tests of VSWR and insertion loss were also conducted. However, it is the field measurements that are of prime importance in a high power evaluation such as this.

For the high power portion of the tests, the AN/FPS-65 radar located at RADC's Verona Test Site was used. Three arbitrary test frequencies, 1270, 1298 and 1330 Mc, were chosen at which the tests were conducted. At 1270 Mc, the radar output power was raised to a normal operating point, 2 MW peak or approximately 4.3 KW average. The antennas of the AN/FPS-65 and field intensity meter NM-62A (located in the far field), were peaked up for maximum energy transfer. The output spectrum of the FPS-65 was then automatically scanned between 1 and 10 Gc. For all frequencies for which a response was noted above the receiver noise level, the receiver was calibrated and the level of the signal determined in $\text{db}/\mu\text{v}$. The open periodic filter was then installed in the radar. Physically it was located approximately midway between the transmitter and antenna. The same

power level was duplicated and a spectrum search of the radar was again performed in precisely the same fashion. The entire test procedure was then repeated for the remaining two test frequencies. VSWR checks across the operating band of the FPS-65 were also made with and without the filter in the system.

The low power lab tests for VSWR and insertion loss were performed in a usual fashion. VSWR measurements were taken using an externally modulated signal generator, a waveguide slotted line, a VSWR meter and a matched dummy load. Insertion loss measurements were performed by the substitution method.

TEST RESULTS

The results of the high power field tests and the low power lab tests are indicated in Figures 2 through 7. Figures 2, 3 and 4 show a comparison of the spectral output of the FPS-65 with and without the open periodic filter for 1270, 1298, and 1330 Mc, respectively. As is apparent from these graphs, at no time, with the filter in the system, was there any indication of a spurious or harmonic response. At each test frequency all spurious and harmonics were reduced to at least below the sensitivity (noise level) of the receiver. Although not indicated in graphs, when the transmitter was tuned to each of the test frequencies, 1270, 1298, and 1330 Mc, the filter began to cut off at approximately 1600 Mc and reached maximum attenuation at about 1750 Mc.

Figure 5 indicates the results of VSWR measurements taken across the operating band of the FPS-65 with and without the filter in the system. Again, as is apparent from Figure 5, the installation of the filter in

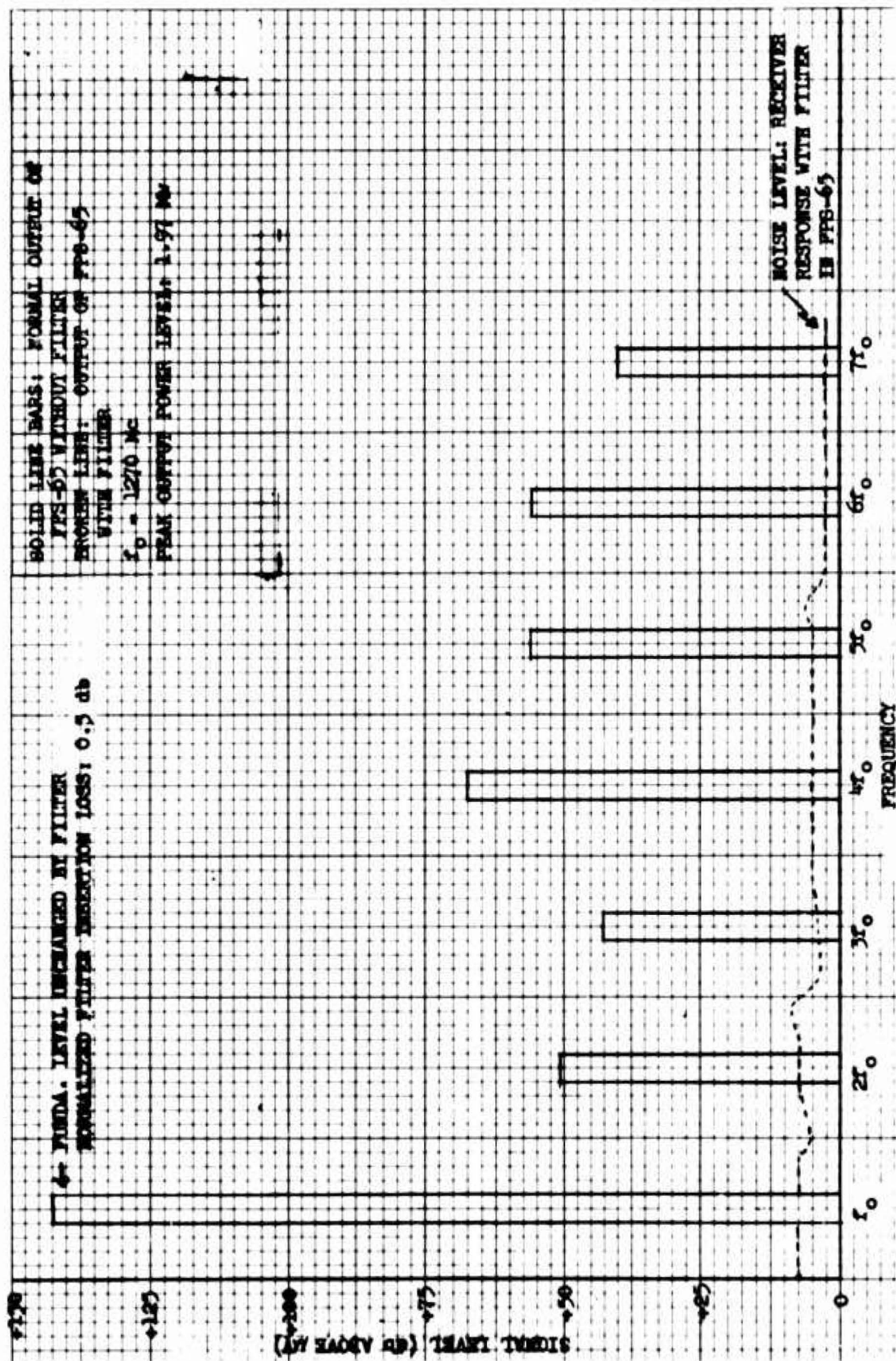


Fig. 2 Fundamental and Harmonic Output of the AN/FPS-65

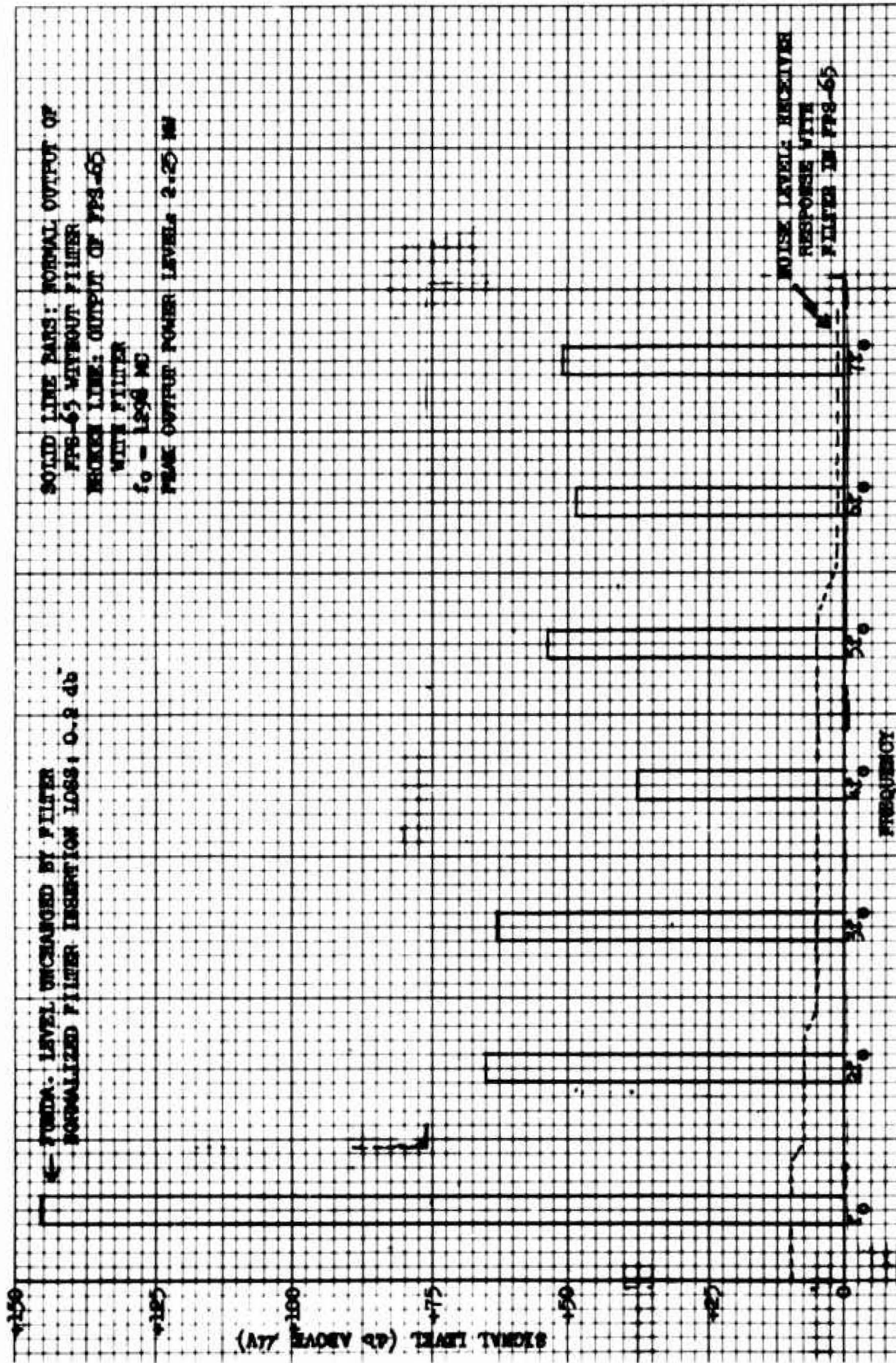


Fig. 3 Fundamental and Harmonic Output of the AN/FPS-65

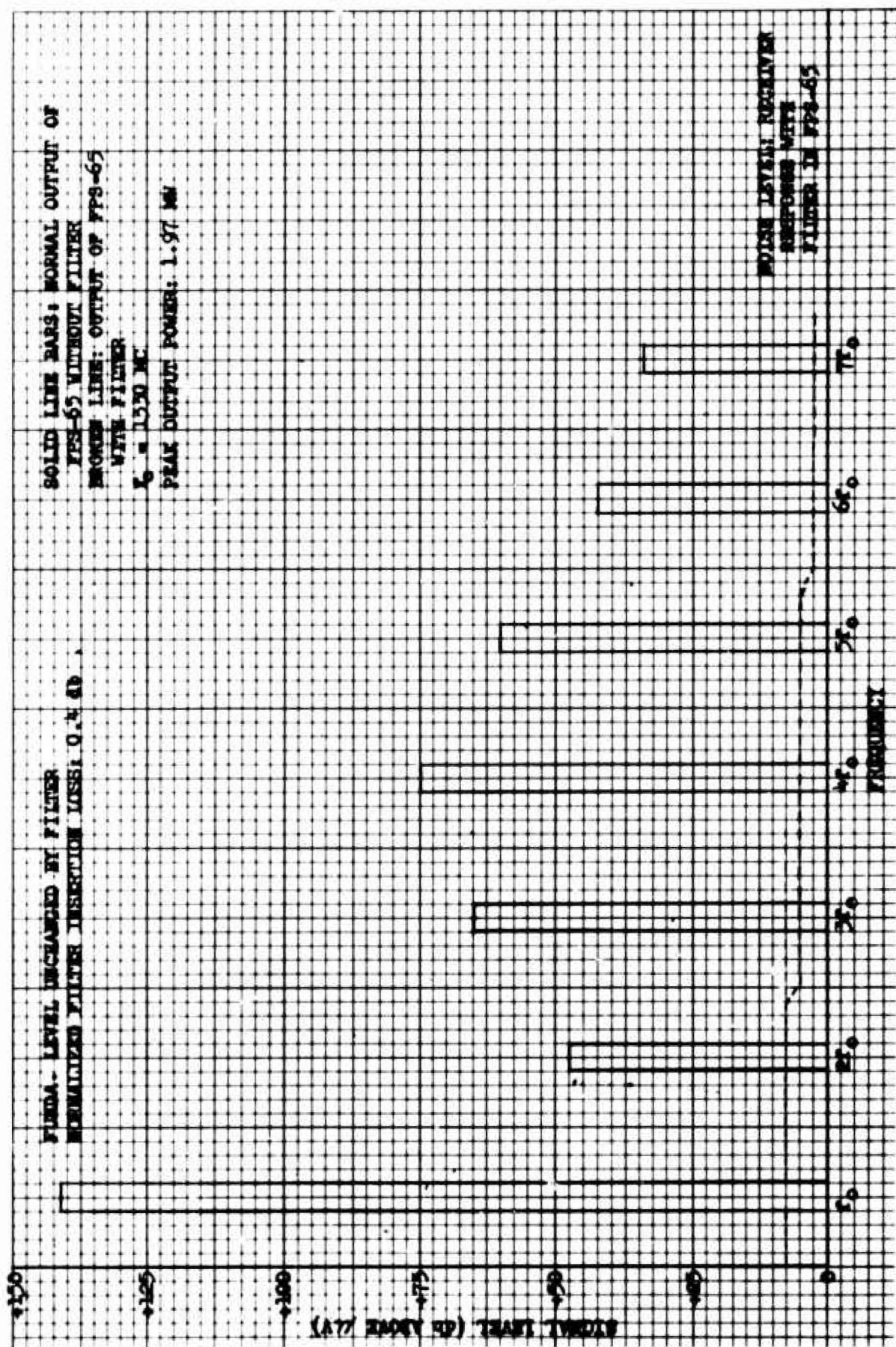


Fig. 4 Fundamental and Harmonic Output of the AN/FPS-65

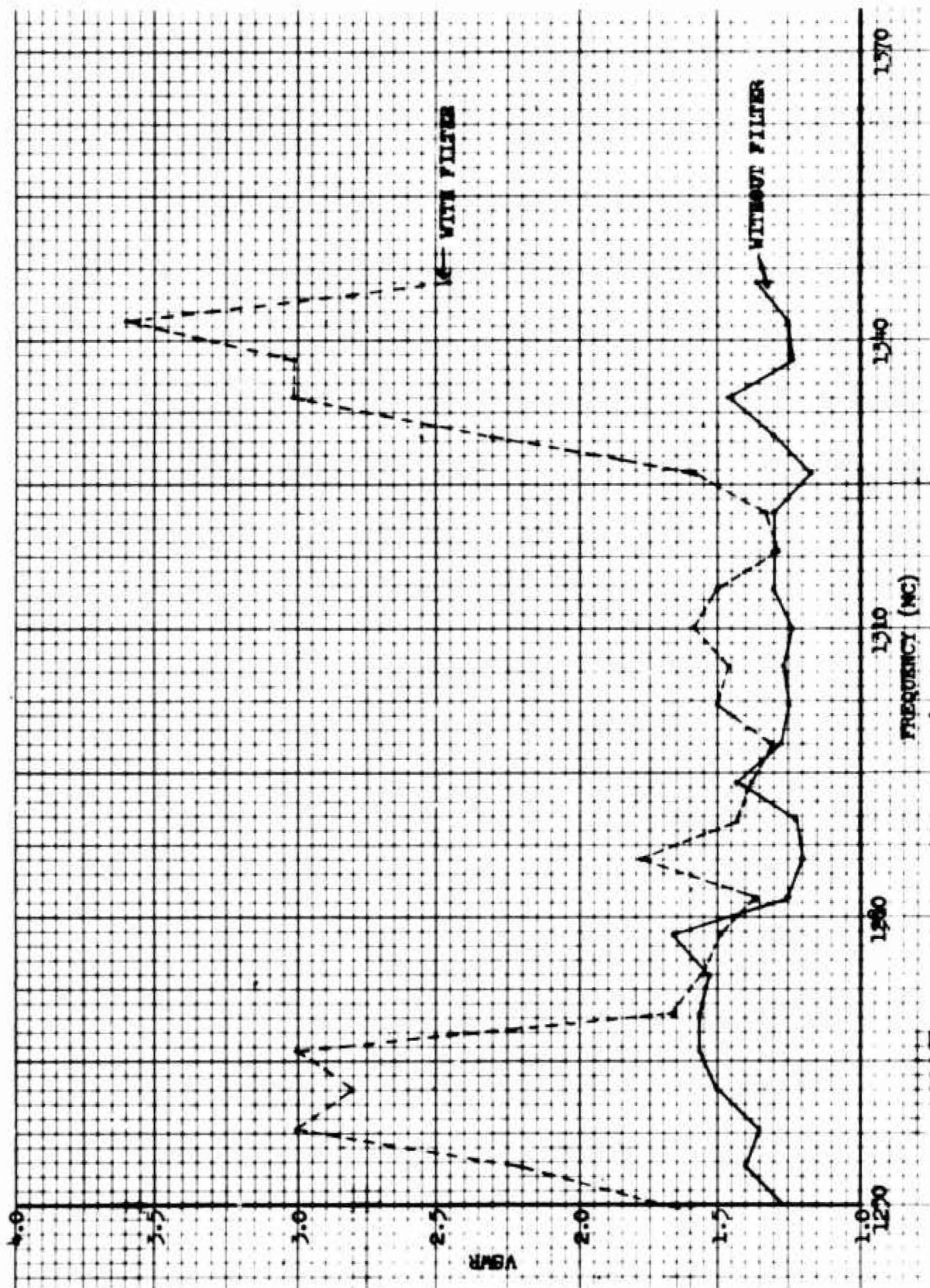


Fig. 5 VSWR of the AN/FPS-65

the system, for the most part, increased the VSWR of the system, especially near the low and high ends of the band. However, it should be remembered that Figure 5 indicates the VSWR of the over-all system; i.e., the FPS-65 plus the filter and not necessarily the VSWR of the filter itself. Figure 6 is perhaps a more accurate representation of the actual VSWR of the filter. This curve, obtained under low power conditions using a waveguide slotted line and a matched dummy load, indicates a substantial improvement over Figure 5 and the significantly better results obtainable under more closely matched conditions. In spite of the high VSWR at certain frequencies, the filter was capable of handling the maximum output power of the FPS-65 at all frequencies without any arcing or breakdown. An indication of the average and peak power output of the radar or the power accommodated by the filter across the operational band, 1250 to 1350 Mc, is shown in Figure 7. During all the high power testing, the filter was pressurized to approximately 10 psig with sulfur hexafluoride (SF_6). Pressurization or a gas is necessary for operation of this filter above a peak power level of 400 Kw. No attempt was made, however, to determine the breakdown power as a function of air or SF_6 pressure, since the maximum power available during the tests was only 2.75 Mw. The filter satisfactorily sustained continuous operation at this power level. In Figure 8, curves are provided which indicate the projected operational power handling capacity of the helix open periodic filter. It is clearly obvious from the graph that the filter is capable of accommodating peak power levels in excess of 10 Mw, for a given environment, when pressurized with one of the high dielectric strength gases.

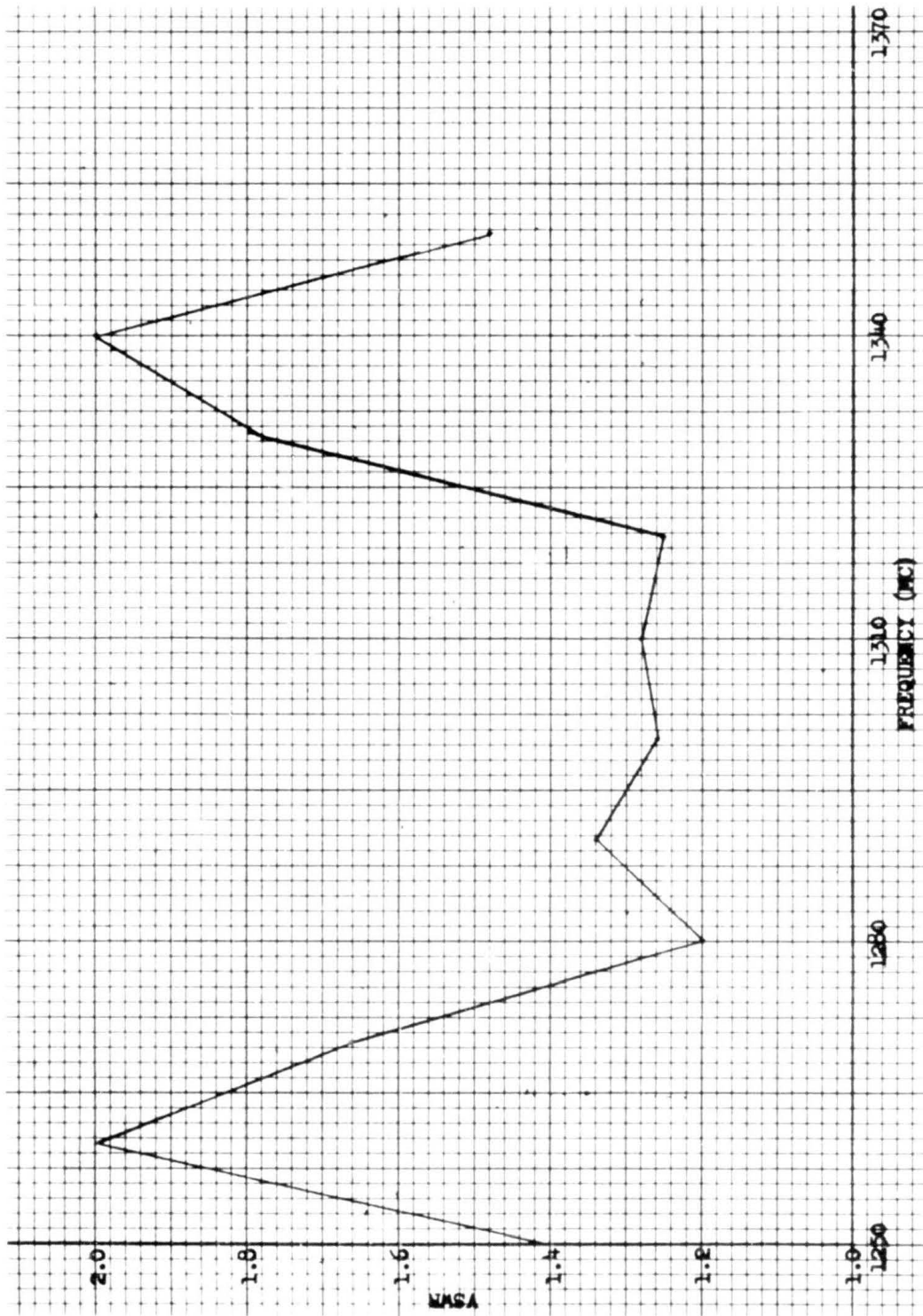


Fig. 6 Pass Band VSWR of the Helix Open Periodic Filter

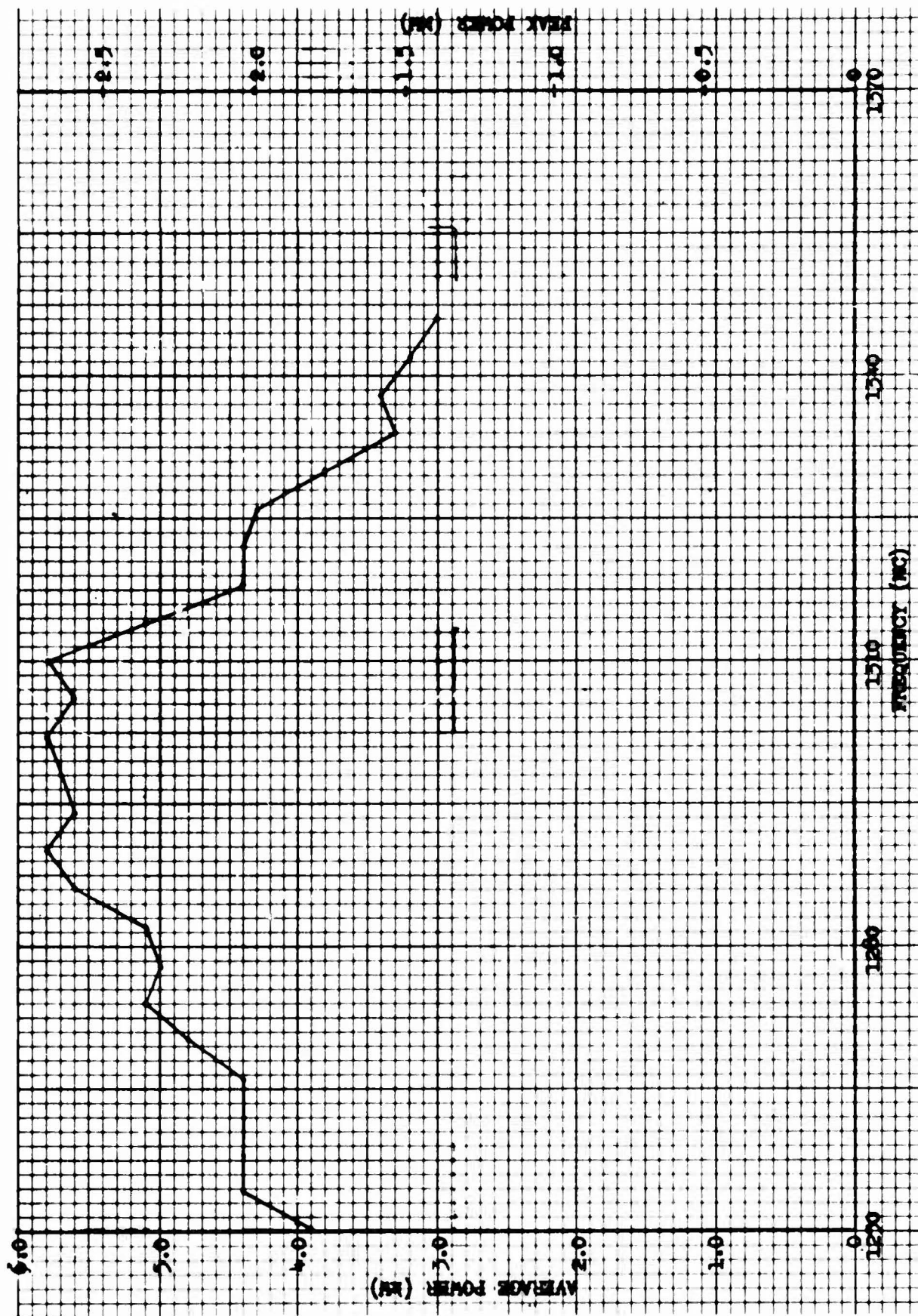


Fig. 7 Peak and Average Power Accommodated by the Open Periodic Filter. Maximum Output of the AN/FPS-65

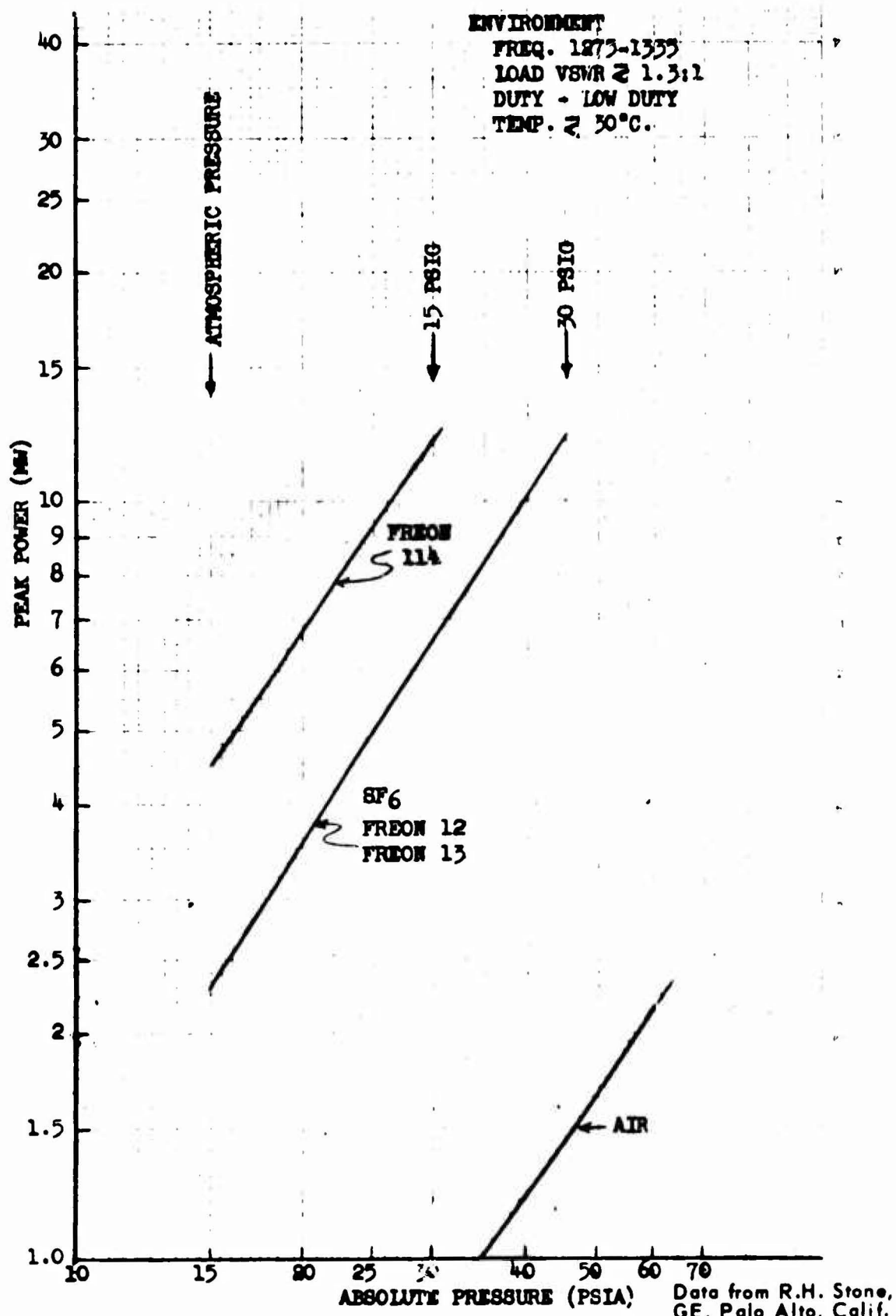


Fig. 8 Helix Open Periodic Filter Operational Power Handling Capacity

The only other test performed on this filter was a check of pass band loss. The results of this test are shown in Figure 9, and they indicate a loss of less than 0.4 db across most of the pass band.

CONCLUSIONS AND RECOMMENDATIONS

This report discussed the high power testing of a helix open periodic filter developed under Contract AF30(602)-2955. Analysis of the test data indicates excellent stop band characteristics with observed rejections as high as 70 db over the stop band tested. Stop band characteristics were only checked out to the seventh harmonic or approximately 10 Gc but the filter is known to have a minimum rejection of 50 db out to at least the 30th harmonic. The multimode field tests indicated that there were no additional pass bands in the stopband, thus providing evidence that the allowed-forbidden region filter principle is solely frequency dependent.

The pass band characteristics for the most part proved to be quite satisfactory. A high VSWR and insertion loss near the high and low ends of the pass band was experienced, but this is strictly a function of waveguide to transition mismatch and can be easily corrected in an operational model. Also, for the feasibility model, VSWR is relatively unimportant since a given bandwidth was neither a design goal nor of prime concern in the design and fabrication of the model or in demonstrating the filtering technique.

As was mentioned in the previous section, the filter easily accommodated the maximum output power of the FPS-65 at all frequencies without evidence of arcing, excessive heating or breakdown of any kind, and

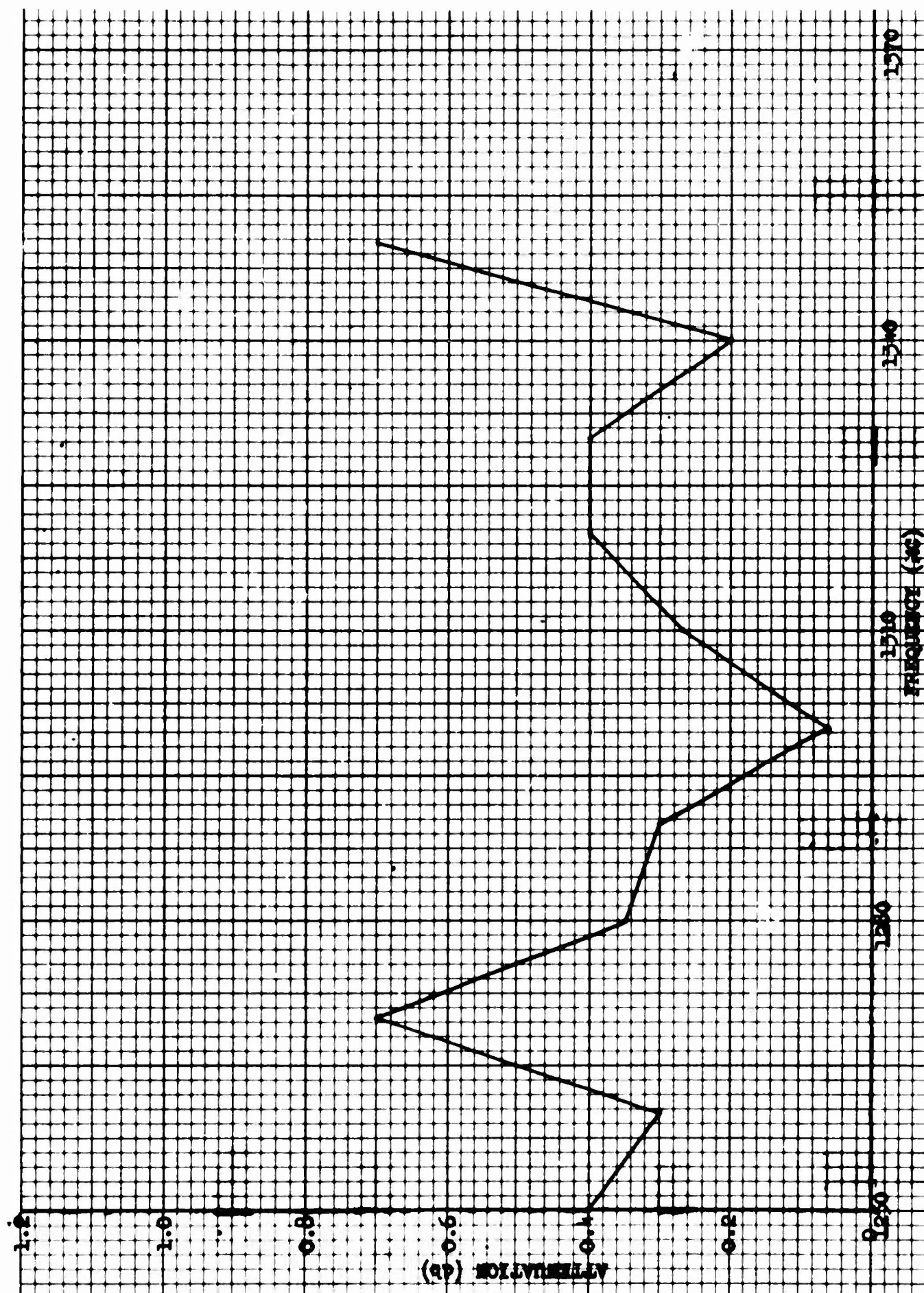


Fig. 9 Pass Band Loss of the Helix Open Periodic Filter

exhibits a projected operational power handling capacity in excess of 10 Mw.

In conclusion, it should be remembered that the filter tested was a breadboard model, fabricated for the sole purpose of demonstrating the feasibility of using the allowed and forbidden regions of open periodic structures for filtering and not an operational model designed for a specific system. Viewed in this light and considering the excellent over-all performance of the breadboard model, the feasibility of using open periodic structures for high power microwave filtering has been clearly demonstrated and is being pursued to exploit its apparent advantages over techniques currently in use.

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